TR-926

A PREDETECTION DIVERSITY COMBINER

R. A. Parkhurst

30 March 1961

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ORDNANCE CORPS ● DEPARTMENT OF THE ARMY
WASHINGTON 25, D. C.

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ORDNANCE CORPS **WASHINGTON 25, D. C.**

DA-5N98-09-003
OMS-5010.21.83006
DOFL Proj 24250

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R. A. Parkhurst

FOR THE COMMANDER:
Approved by

R. D. Hatcher
R. D. Hatcher
Chief, Laboratory 500

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ABSTRACT

A two channel, predetection diversity combiner is described. The combiner uses two commercial telemetry receivers as a basis; the necessary subchassis were constructed to (1) combine the expected signal from two antennas to improve the signal-to-noise ratio and (2) measure the relative phase of the signals at the two antennas.

Photographs demonstrate the improved signal-to-noise ratio of the system.

1. INTRODUCTION

Diversity combining is the process of using two or more signals of identical intelligence received from two or more sources to produce a more reliable signal containing the desired intelligence. One combination method is the use of two receiving systems to receive two different carriers with identical modulation and combining the detected outputs of two receivers. Such a system is termed a post-detection frequency diversity system.

Similarly, diversity may be accomplished by receiving a single transmitted signal through two antenna systems and separate receivers, the antennas being at different locations. Since the same carrier is to be received by both receivers, it is possible to combine the signals in the receivers before detection. This type of system is called a predetection space diversity combiner.

Other methods encompass time diversity, signal selection diversity, and polarization diversity. In all cases a statistical improvement in signal-to-noise ratio is obtained. Thus, the goal of combining is to assure that, should one signal channel fail due to fading or other reasons, the other will still provide the signal.

Diversity differs from redundancy in the following manner: An AM dual-channel pre- or post-detection combiner system with a unity signal-to-noise ratio in both channels can provide up to 3 db improvement in signal-to-noise ratio over the signal in either channel. This increase depends upon the system used and is due to the signals in each channel being coherent, whereas the noise in the individual channels is uncorrelated.

A thorough discussion of diversity is not attempted here since numerous articles are available in the literature. One comprehensive article is Linear Diversity Combining Techniques by D. G. Brenan, IRE Proceedings, June 1959.

2. DESCRIPTION OF COMBINER

A dual-channel diversity combiner was constructed based primarily on two dual IF telemetry receivers. The receiving system contained two antennas, space and polarization diversified, two dual IF receivers, three FM detectors and the combining circuitry.

The overall system was designed to serve two purposes; first, the relative phase between the signals in the two antennas was to be measured. This phase was expected to change at rates up to 30 rad/sec. Secondly, the signals from the two antennas were to be combined as a space diversity receiving system. This paradoxical situation was resolved by using both of the IF amplifiers in each receiver and some additional circuitry to mix the LO of one receiver with the signal in the other.

A block diagram of the overall system is shown in figure 1. The first LO's of each receiver were tied together so that the two 30-Mc IF's obtained from the same carrier entering each antenna would be identical. One common LO could have been used, but should it have failed, the whole system would have been inoperative.

In receiver 2 the 30-Mc signal is converted to 5 Mc by the second LO. This signal is amplified by IF amplifier 2a and fed to one input of a phase comparator.

The 30 Mc of receiver 1 is converted to 5 Mc by its second LO. The frequency of this LO is voltage controllable, however, and is maintained at the proper frequency necessary to keep the 5-Mc IF in amplifier 1a identical with the 5 Mc in amplifier 2a. The two 5-Mc signals are phase locked by the phase comparator, in which the 5 Mc from IF strip 2a is compared with the 5 Mc from IF strip 1a. Any error voltage generated due to phase differences is used to control the LO of receiver 1.

Thus the two 5-Mc signals are phase coherent. The phase detector maintains an inherent 90° shift between the two signals, so the function of the adder is to shift one signal $+45^{\circ}$ and the other -45°, thereby placing them in phase addition. The two signals are then added in a common plate load in the first limiter stage of a conventional limiter-discriminator detector.

AGC voltage developed by the detector is fed to both 30-Mc IF amplifiers and the 5-Mc amplifiers used for the combiner. This assures that, should the signal fade in one channel, the AGC generated by the signal from the other channel will suppress the gain of the low signal channel and thereby hold down the noise fed to the combiner from that channel.

The two 30-Mc IF signals (one in each receiver) will differ in phase due to the relative location of the transmitter to the two antennas. Also, in the case of a spinning transmitter, the polarization of the antennas, one RH and one LH, causes a frequency difference in the two receivers equal to the spin rate of the transmitter.[1/]

[1/] Double Sideband Suppressed Carrier Modulator - Case OD 1205 Patent Disclosure (DOFL), J. A. Kaiser

The rate at which the controlled LO must be able to correct is determined by inequalities in the phase response by the two IF amplifiers and spin acceleration of the transmitter; that is, with no modulation, if the 30-Mc signals differed by 10 cps, the controlled LO would have to be held 10 cps from the uncontrolled LO. The rate at which the spin varied from 10 cps to some other value would govern the response time required by the LO control loop. This would normally be a very slow rate -- on the order of a few cps.

As soon as frequency modulation is applied to the carrier, the 30 Mc in each receiver will deviate. As the deviation takes place, the only difference between the two signals will be due to differences in phase slopes of the two systems. The rate of phase change will be the modulation rate times the phase rate difference, which would place very-high-frequency response requirements on the control system. The major limiting factor in upper frequency response is the signal delay time through the 5-Mc IF strip. This delay time actually limited the response of the control system to around 10 kc under its best operating conditions.

Figure 2 shows, from top to bottom, the response curves of channel 1b, 2b, and the combined channel. As can be seen the response curves are not identical, and the signals in any two channels would experience phase anomalies when modulated.

Figure 3 shows Lissajou patterns of the phase relation between the two 5-Mc IF signals at the upper and lower limits of the IF passband. This picture was made with an unmodulated carrier tuned plus and minus 250 kc from the center frequency. Figure 4 shows a Lissajou pattern generated by (a) an unmodulated carrier and (b) a carrier deviated about ±200 kc at a 1-kc rate. As would be expected from the two ellipses at the edge of the passband (figure 3), the modulated signal causes a blur as the elliptical trace changes dimensions.

Figure 5 shows the effect of reducing the signal in each channel. The upper trace represents No. 1 signal output (see block diagram). The middle trace represents No. 2 signal output and the lower trace is the signal from the detector of the combined IF amplifiers. This picture demonstrates the ability of the system to suppress the noise generated by either channel when the signal in that channel is lost.

Figure 6 shows the ability of the combiner to "pluck a signal from the noise." Here the signals in both receivers were reduced until they became obscured by noise. The combiner, due to its extra improved signal-to-noise ratio, was able to produce a still visible signal.

In all cases the photographs were made using the modulation source as the synchronizing signal to the oscilloscope.

Returning to the block diagram, it is seen that the second LO of receiver 2 is sampled, amplified and mixed with an amplified sample of the 30-Mc IF of receiver 1. The 5 Mc in IF 1b thus is a heterodyned replica of the signal in antenna 1 and the 5 Mc in IF 2b similarly represents the signal in antenna 2. If, due to spinning, the frequencies differ in channel 1 and channel 2 by a few cps, the phase detector comparing IF's 1b and 2b will deliver an output frequency proportional to the spin rate.

In the bench set up, one receiver was fed from a signal generator through a slotted line, the other receiver was fed from the tap on the line. In this manner, the relative phase of the RF entering to the two receivers could be varied by sliding the tap along the line. As the tap was moved, the phase angle was represented by a positive or negative voltage at the phase detector, while the amplitude of the signal from the combiner detector remained constant.

If the tie between the two first local oscillators were removed, the 30-Mc IF's would differ by about 30 kc. By retuning the combiner second LO slightly, the 5-Mc IF's could be phase locked together, that is, the two second local oscillators would be locked about 30 Kc apart, thus presenting two identical 5 Mc signals to the combiner phase comparator. The overall system did not work so well under these conditions as when the first LO's were tied together. Also, when operating with the first LO's unlocked, the difference frequency would be displayed in the output of the RF phase measuring detector.

Figures 7, 8, 9, and 10 are schematic diagrams of the various subchasses used in the diversity combiner.

The author wishes to express appreciation for the work performed by Mr. Nicholas DiMario in the layout and construction of the combiner subchassis.

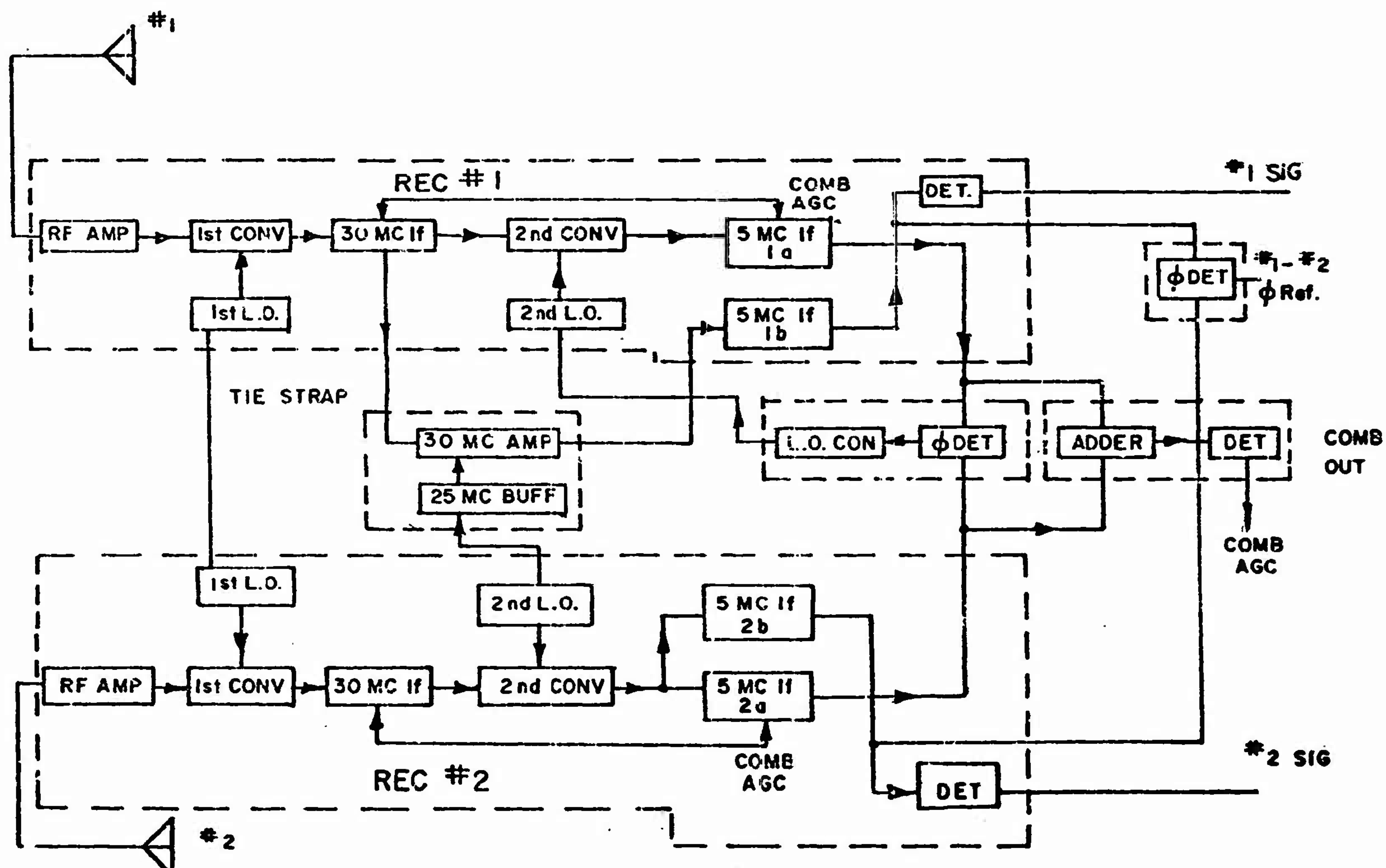
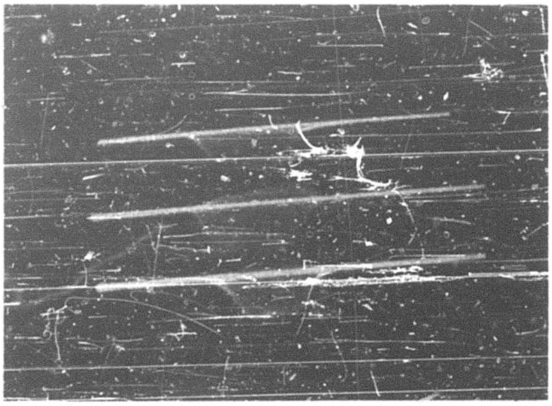


Figure 1. Predetection diversity combiner, block diagram.



Passband of 5 mc IF amplifier 1b

Passband of 5 mc IF amplifier 2b

Passband of combined 5 mc channel

Horizontal sweep is about 300 kc per division

Figure 2. Response Curves

Carrier deviated
+ 250 Kc from
center frequency

Carrier deviated
- 250 Kc from
center frequency

Vertical signal is 5 Mc IF
from channel 1

Horizontal signal is 5 Mc IF
from channel 2

Figure 3. Phase relationship betweeen 5 Mc IF signals of channels 1 and 2 at edges of IF passband.

Carrier un-
modulated

A

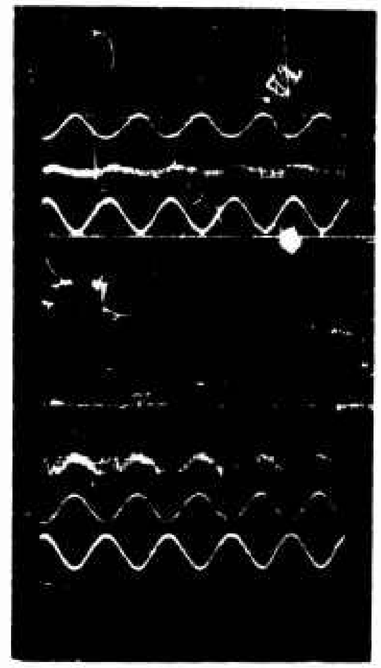
Carrier
deviated
200 Kc at
1 Kc rate

B

Vertical signal is 5 Mc IF
from channel 1

Horizontal signal is 5 Mc IF
from channel 2

Figure 4. Phase relationships between 5 Mc IF signals of channels 1 and 2.



Signal in channel 2 reduced to noise level - Combined output remains clean

signal out channel 1

signal out channel 2

signal out combined channel

Signal in channel 1 reduced to noise level - Combined output remains clean

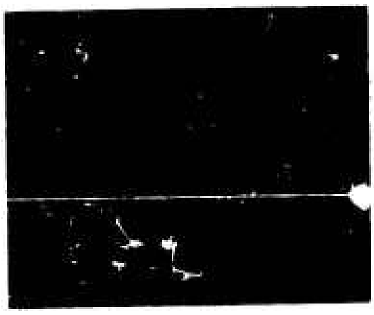
signal out channel 1

signal out channel 2

signal out combined channel

Figure 5. Ability of combiner to retain signal output when one channel fades.

Signals in both
channels reduced
to below noise level-
Combined output still
produces signal



signal out
channel 1

signal out
channel 2

signal out
combined channel

Figure 6. Ability of combiner to retain signal output
when both channels fade.

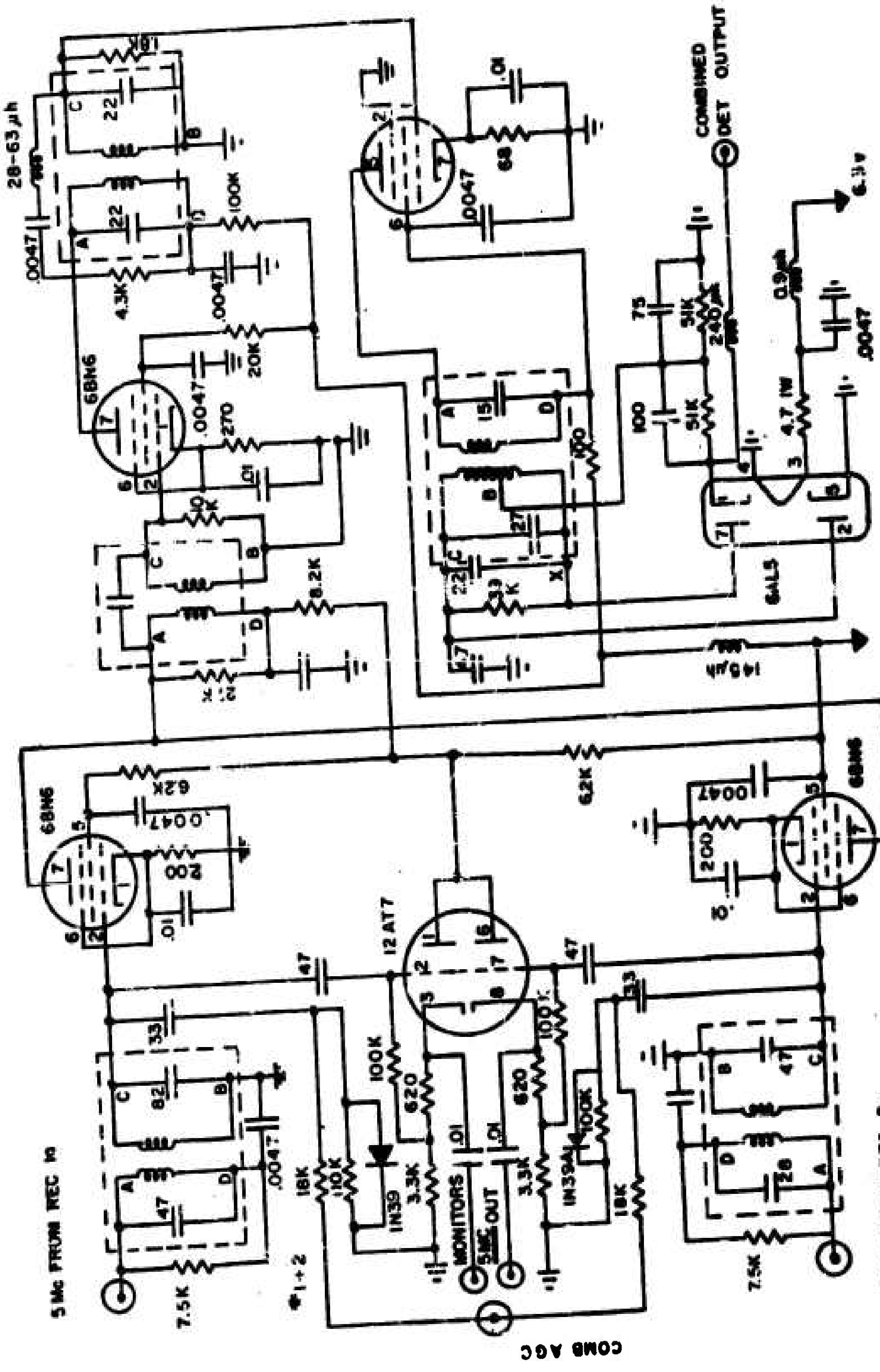


Figure 7. Combiner chassis.

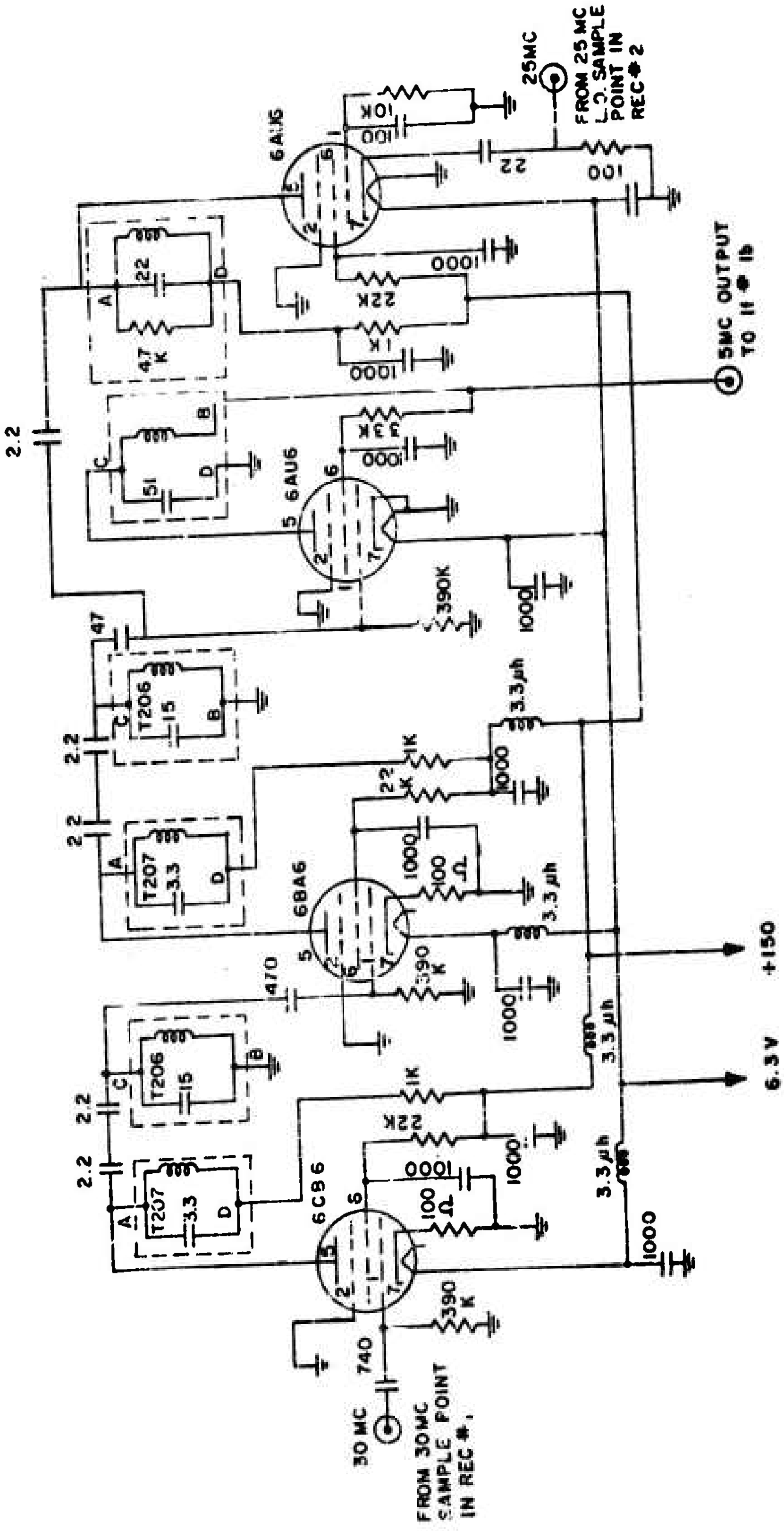


Figure 8. Converter Chassis.

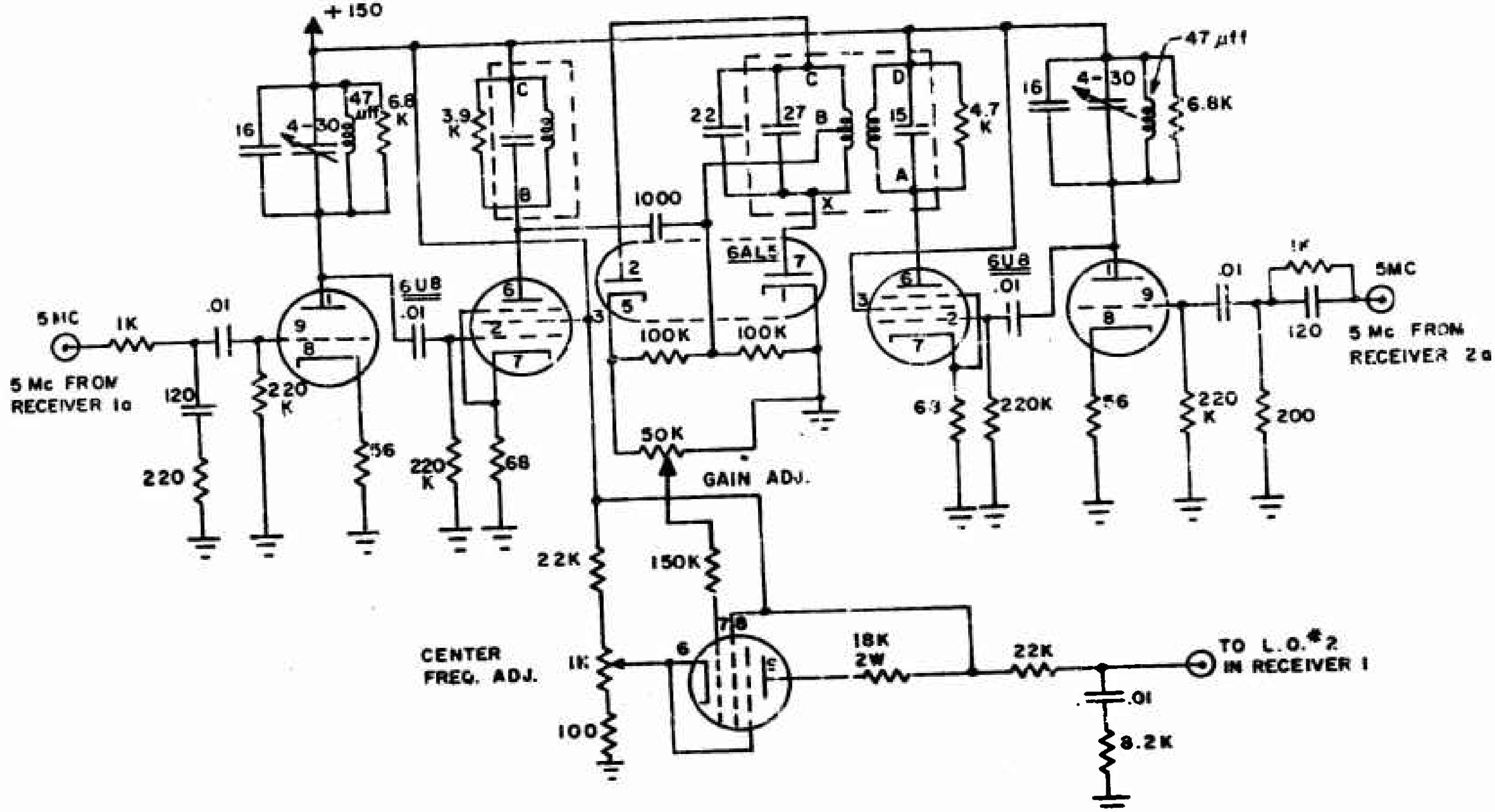


Figure 9. Local oscillator control chassis.

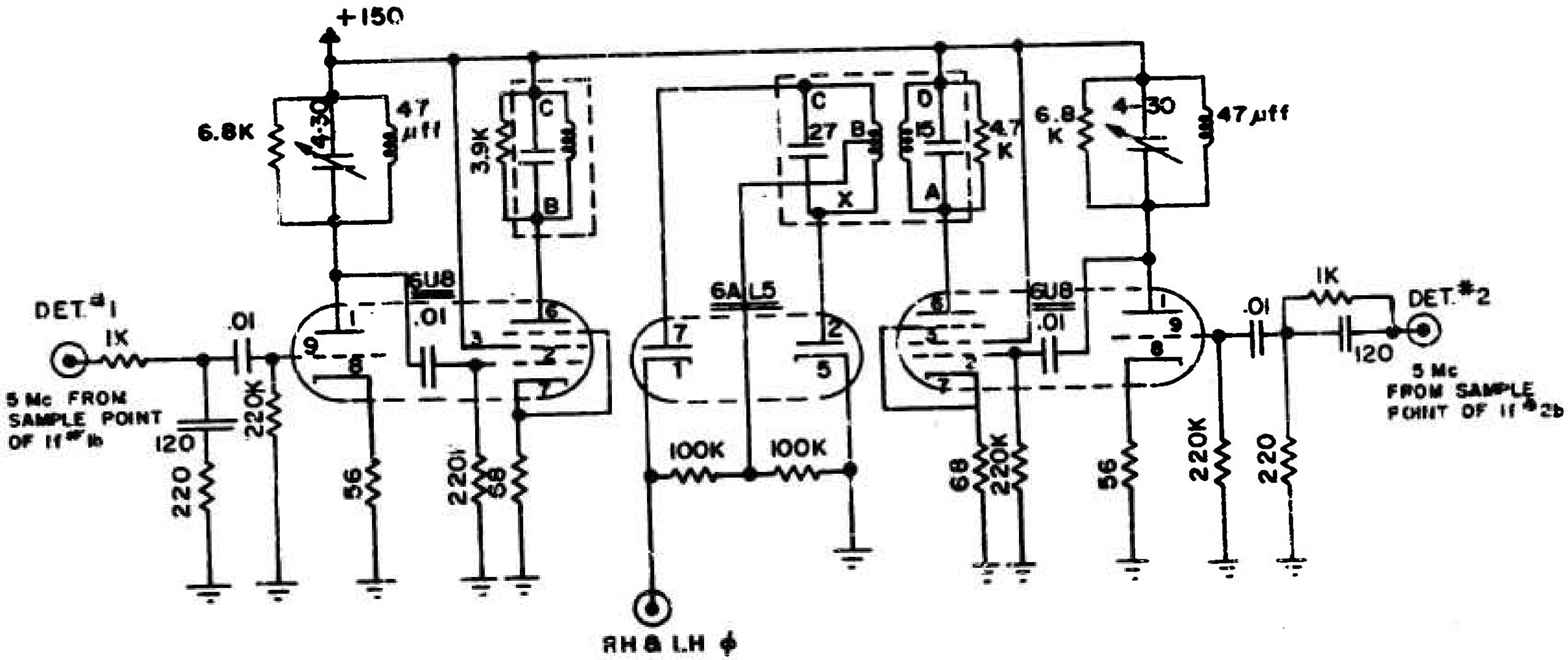


Figure 10. Channel 1 and channel 2 phase detector chassis.

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Photographs demonstrate the improved signal-to-noise ratio of the system.

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